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Cause and Effect Relationship of Some Growth and Yield Traits in Cucumber (*Cucumis sativus* L.)

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Abstract:

The effectiveness of a breeding program can usually be determined through the direction and size of the contribution of yield traits, whereas a proportional relevance of each trait is involved in its contribution towards yield. Practical knowledge of this phenomenon would aid in the decision-making process for the concurrent development of many traits in a breeding program. The present experimental investigations were carried out in the Alsayla area, Ibb Governorate in Yemen, from February to May 2021 with a set of thirteen cumber cultivars planted as a triplicated randomized complete blocked design (RCBD) under a protected greenhouse to examine the cause-effect relationship among growth, yield, and its contributing traits for cucumber. For the determination of the direct and indirect impact on yield, the path analysis was performed using genotypic correlation coefficients as input. Both objectives were studied for different characteristics like Vine length (cm), Leaf Area (cm^2), Fruit Weight (g), Total Soluble Solids (TSS), Fruit diameter (cm), and dry matter (%), as well as fruit yield plant^{-1} (g). Genotypic and phenotypic correlation results revealed that yield had a highly significant positive correlation with fruit weight, leaf area, fruit diameter, dry matter, TSS (Brix°), and the path coefficients for genetic correlation coefficients showed a positive direct effect. These traits should thus be prioritized in the selection process for developing cucumber varieties with high yield potential.

Keywords: Association, correlation, path analysis, controlled greenhouse, fruit yield, cucumber.

Introduction:

Cucumis sativus L., commonly known as cucumber, is considered the principal vegetable crop globally. It is ranked fourth, following tomato, cabbage, and onion (Tatlioglu, 1993). Cucumber is included in the Cucurbitaceae family, having more than 120 genera as well as many species, i.e., over 800 (Rubatzky and Yamaguchi, 1999). The genus Cucumis is considered to roughly contain 30 different species divided into two major groups and found to be distributed across two diverse geographical locations. It has been discovered growing as wild as early as more than 3000 years with a probability of having origin through India. It has also been spread west to Southern Europe, North Africa, and Asia Minor, whereas east to China (Renner et al. 2007; Chomicki et al. 2020). Wild cucumber, semi-wild cucumber, and cultivated cucumber are the three types of cucumber (Che and Zhang 2019). In terms of the conventional form, Sir Joseph Hooker reported Cucumis sativus var. hardwickii Kitamura, also known as Indian wild cucumber found to grow as wild across Himalayan foothills as feral or might be a progenitor for the modern world cucumber. Issihiki et al. conducted six isozyme studies of Indian wild cucumber and provided comparable and robust recommendations on this topic (1992); fruits range in size from 5 to 40 cm in length and have a spherical to cylindrical form (Grumet et al., 2017). The Asiatic group of cucumbers has been reported to be grown wild across South & East Himalayas with chromosome number 2n = 2x = 14. Moreover, the African group of cucumbers, including Cucumis anguria L., also known as West Indian Gherkin and Cucumis melo L., commonly known as muskmelon has a chromosome number of 2n = 2x = 24, were reported to be wildly growing across the Middle East as well as African countries (Naegele and Wehner, 2016; Bhaiya et al., 2020). Producing vegetables may help reduce poverty by increasing farmer income in underdeveloped nations. Cucumber is considered among the most important crops in terms of production, yield, area under cultivation, commercial usage, as well as consumption and is commonly farmed in a plastic house around the globe throughout the year. In 2019, it produced 87.80 million tons over 2.23 million hectares of cultivated land. China accounted for 70.34 million tons (80.11 %) of global output in 2019 from 1,258,370 hectares (56.39 percent) of cultivable land (FAO, 2018), with China leading the way to Turkey and Iran. In Yemen, cultivated land and output increased by 924 hectares and 13,870 tons, respectively, in 2017. Cucumber is rich in vitamins and minerals (Okonmah, 2011). It's planted for its soft fruits, which may be eaten fresh in salads, cooked as a vegetable, or pickled when young (Sharma et al.,2020; Sallam et al., 2021). In order to fulfill the local demand for this commodity, it is necessary to advance this crop by generating improved varieties and hybrids.

Correlation and path coefficient analyses are critical tools for determining the different yield components, resulting in better genotype selection. Thus, for a sensible approach to yield improvement, it is critical to know the mix of various yield components and their proportional effect on yield. Numerous studies have examined the correlation and path coefficients between key yield components in crops such as tomatoes in order to maximize production (Javed et al., 2021); cucumber was also mentioned by (Singh et al., 2002; Rao et al., 2004; Afangideh and Uyoh, 2007; Patil 2009; Sharma et al., 2018, 2020; Manivannan et al., 2020, and Bhaiya et al., 2020), cotton (Raza et al., 2021), barley (Soleimani et al., 2017), rice (Agahi et al., 2007; Salleh et al., 2020), finger millet (Chavan et al., 2020), pea (Khan et al., 2017), groundnut (Prabhuet al., 2014), and maize (Hakim et al., 2021). The significance of causal relationship as reported by several researchers viz. in rice by Rao et al. (1991), barley by Dofing and Knight (1992), wheat by Blue et al. (1990), groundnut by Manoharan et al. (1990), pea by Singh et al. (1985), maize by Singh and Singh (1993) and sugarcane by Ram and Hemarpabha (1991), as proposed through Wright (1921), and the model used was almost similar to Dewey and Lu (1959). In this model, bidirectional causation between yield and yield contributing traits has been assumed. Path coefficient analysis is based on the determination of a causal relationship across various variables on the basis of either a so-called priori evidence or maybe through a supposed hypothesis. Yield contributing traits may develop a sequential through a later-developing component through earlier-developing one's control (Fisher and Palmer 1983, Dofing and Knight 1992). The analyses of correlation coefficient values for various traits with yield may help decide their relative influence, whereas value is considered for selection criteria for the ability to be higher-yielding. Path analysis determines the relative importance of each trait (Wright 1921; Dewey and Lu 1959). In the contrary, correlation alone may not have the capability to provide basic knowledge about the contribution by related traits, which might require specified study about cause-and-effect relationships across various traits among themselves and traits that contribute to crop productivity (McGiffens et al., 1994). Thus, selection for yield on the basis of the combination of several contributing traits is consistently superior as compared to selection for yield on the basis of yield solely. Yield is considered the quantitative attribute regulated by a large number of genes (Lungu 1978). Breeders must sufficiently understand the crop's size and degree of association with its qualities or components. Educators will better understand the strength of associated features, which will benefit the selection process for the simultaneous development of several personalities (Sivaprasad 2008). Kramer and Wehner (1998) noted that selection of qualities that are closely connected to the crop but have a greater genetic vulnerability has the opposite effect of indirectly increasing production. Correlation studies between cucumber growth, quality attributes, contributing factors, and their proportional contribution to yield would be very beneficial in designing and assessing the salad cucumber breeding program. While the correlation coefficient reflects the nature of the relationship between the qualities, route analysis divides the correlation coefficients into direct and indirect impact measurements, implying the concept that correlation analyses are less powerful than that path analyses (Dewey and Lu, 1959). Thus, it explains both the direct and indirect contributions of each character towards yield. Thus, correlations in conjunction with path analysis provide a more complete picture of the cause-and-effect relationship between a pair of characters. The current study evaluated exotic and indigenous cucumber varieties/cultivars to ascertain the cause-and-effect relationship between growth, yield, and contributing traits in cucumber.

Materials and methods:

The presented study was conducted at Alsayla area, the location is with 1990 m above the sea level, with temperature varied from 18-29 °C and the relative humidity recorded was 65-75 percent, Ibb Governorate, Yemen, from February to May 2021. The present experimental material comprised 13 diverse bizarre varieties from china and local varieties/hybrid cucumber genotypes. The Experiment was planned and executed as a triplicated Randomized Block Design (RCBD) with thirteen genotypes under a plastic house. The seeds of genotypes considered for the current study were planted in a small plastic house(nursery), for seedling production, and then the seedling is transplanting with a plant spacing of 45 x 75 cm to accommodate ten plants in each replication. Following local practices, cultural practices have been adopted to ensure proper growth and a healthy crop stand. The irrigation practices were conducted by drip irrigation, organic and mineral fertilizers were added according to the practice of farmers in the area, and fruits were harvested early in the morning twice a week.

Data were recorded from five randomly selected plants from each replication related to seven growth, yield, and yield-related traits, including Vine length (cm), Leaf Area (cm^2), Fruit Weight (g), Fruit Diameter (cm), Total Soluble Solids (TSS), Dry Matter ((DM %), %), Fruit yield $Plant^{-1}$ (g). The length of the vine was measured using the cloth meter, according to the average diameter of the stem at the middle of the third branch from the soil's surface using Vernier Caliper. Leaf area (cm^2) by three leaves per plant was used for leaf area determination, was recorded for each plant and the average was used for the analysis. The multiplying calculation of leaf width measured it, and leaf length. According to Yang (1981), Five fruits were randomly taken from each experimental unit, cleaned well, cut, and taken from 50 gm. They were dried using an Air oven of Isotemp oven until the weight was stable, and the dry matter% was calculated according to the equation:

Dry matter (%) = Dry weight/Fresh weight*100.

The individual weight of 15 fruits in the maturity stage was recorded from each experimental unit. The average weight of one fruit was calculated through the average weight of all individually weighted fruits. The percentage of total soluble solids in the fruits was measured using a hand refractometer of the type Abbe, at room temperature, by taking three readings in a clear solution prepared from each sample directly, from cucumber juice in the maturity stage from each reap(harvest).

The data were organized using the Excel program, then the correlation coefficient between the studied traits was calculated using the program SAS software. The data were subjected to correlation coefficients analysis following Al-Jibouri *et al.*, (1958) and path analysis as proposed by Dewey and Lu (1959).

Results:

Tables 1 and 2 illustrate the correlation coefficients among traits under study at phenotypic and genotypic levels. The values of genotypic correlation coefficients have been often observed as greater than the size of phenotypic correlation coefficients. This might be viewed as an indication that a strong intrinsic genotypic link between the traits examined through their phenotypic manifestation was harmed by environmental impact. Based on phenotypic correlation it is shown that the parameter vine length (VL), leaf area (LA), fruit weight (FW), fruit diameter (FD), and total soluble solids (TSS) showed a significant positive yield per plant with level 1% (0 .9351, 0.985, 0.9854, 0.9893, 0.929, and (0.876) respectively.

The result has shown a high significant phenotypic correlation**,** and positive on Fruit weight with Fruit Diameter (1.0014), followed by leaf area (0 .9738), and TSS (0.9558), the phenotypic correlation raveled non-significant between Vine Length with Fruit Weight (0.4118), Fruit Diameter (0.2947), total soluble solids (0.1254). leaf area is a phenotypic correlation with FD (0.9267)**,** total soluble solids (0.8575), and vine length (0.6298) shown highly significant. The results of Genotypic correlation (Table-2) revealed that yield had a highly significant positive correlation with fruit weight (0.8718) followed by leaf area (0. 8625), Fruit diameter (0.7362), and TSS (0.7053). leaf area showed a highly significant positive correlation with FW (0.9092), Fruit diameter (0.8522), dry matter (0.8563) DM, and TSS. (0.743). Fruit weight revealed a highly significant positive correlation with both FD (0.798), dry matter (0.9664), and TSS (0***.8769***).

Path coefficients analysis was estimated on phenotypic and genotypic levels to resolve distinct features' direct and indirect influences on fruit yield per plant (Table-3). Fruit diameter (15.0767) had the most significant direct effect on fruit yield per plant, followed by Vine Length (11.3312), and TSS (6.1378). Leaf area (-20.9383) and fruit weight, on the other hand, had a negative and direct impact on the yield (-12.3339). However, fruit diameter, dry matter, total soluble solids, and vine length had a favorable indirect effect on yield per plant.

The highest positive indirect effects of FW (15.0982), DM (15.087), TSS (15.0829), LA (13.9719), and FD (8.1886), were observed on yield per plant. Maximum negative indirect effects FW (-20.3893), FD (-19.4039), DM (-19.2216), TSS (-17.9546), and VL (-13.1874) via harvest duration were noticed on yield per plant.

Table 1 Phenotypic correlation coefficients of some yield and quality traits in cucumber cultivars.

VARIABLES	Vine Length	Leaf Area	Fruit Weight	Fruit Diameter	Fruit Dry Matter	Total Soluble Solids	Yield / Plant
Vine Length	1.000						
Leaf Area	0.6298 **	1.000					
Fruit Weight	0.4118	0.9738 **	1.000				
Fruit Diameter	0.2947	0.9267 **	1.0014 **	1.000			
Fruit Dry Matter	0.2711	0.918 **	0.9871 **	1.0007 **	1.000		
Total Soluble Solid	0.1254	0.8575 **	0.9558 **	1.0004 **	0.9749 **	1.000	
Yield Per Plant	0.4954 *	0 .9351 **	0.9854 **	0.9893 **	0.929 **	0.876 **	1.000

Table 2 Genotypic correlation coefficients of some yield and quality traits in cucumber cultivars.

VARIABLES	Vine length	Leaf Area	Fruit Weight	Fruit Diameter	Dry Matter	Total Soluble Solids	Yield / Plant
Vine Length	1.000						
Leaf Area	0.5414 *	1.000					
Fruit Weight	0.2815	0.9092 **	1.000				
Fruit Diameter	0.2666	0.8522 **	0.798 **	1.000			
Fruit Dry Matter	0.1182	0.8563 **	0.9664 **	0.7759 **	1.000		
Total Soluble Solid	-0.0643	0.743 **	0.8769 **	0.6807 **	0.8904 **	1.000	
Yield Per Plant	0.4171	0.8625 **	0.8718 **	0.7362 **	0.8172 **	0.7053 **	1.000

Table 3. Direct (Parenthesis) and indirect effect matrix for some yield and quality traits in cucumber.

VARIABLES	Vine Length	Leaf Area	Fruit Weight	Fruit Diameter	Fruit Dry Matter	Total Soluble Solids	Yield/Plant
Vine Length	**11.3312**	-13.1874	-5.079	4.4429	2.2181	0.7697	0.4954
Leaf Area	7.1366	**-20.9383**	-12.0105	13.9719	7.5121	5.2632	0.9351
Fruit Weight	4.6661	-20.3893	**-12.3339**	15.0982	8.0775	5.8667	0.9854
Fruit Diameter	3.3391	-19.4039	-12.3514	**15.0767**	8.1886	6.1403	0.9893
Fruit Dry Matter	3.0715	-19.2216	-12.1748	15.087	**8.183**	5.984	0.929
Total Soluble Solid	1.421	-17.9546	-11.789	15.0829	7.9779	**6.1378**	0.876

[NOTE: Dependent variable is yield. The last column shows correlations of independent variables with yield].

Discussion:

Correlations between certain features and yield are critical in the indirect selection of genotypes for yield enhancement (Machikowa and Laosuwan, 2011). A substantial and positive association between two traits indicates that they may be enhanced concurrently in a selection procedure (Fayeun et al., 2012). It demonstrates the reciprocal interaction between personalities, as selecting one results in the selection and enhancement of the other (Fayeun et al., 2012). Fruit yield per plant exhibited a positive and significant correlation with vine length, leaf area, fruit weight, fruit diameter, dry matter, and TSS, all of which had a positive effect on yield; these findings concur with those of (Ramirez et al.,1988; Afangideh et al.,2005; Kumar,2011; Chikezie et al., 2016, and Nandi et al.,2019). Cucumber likewise exhibits a strong significant positive association between fruit size and total fruit yield (Ullah et al., 2012.). This indicates that selecting for such traits will result in increased fruit yield. These findings were corroborated by (Islam et al. 1993; Sharma and Bhutani 2001; Bhaiya et al., 2020), who found a substantial positive relationship between these features and cucumber production. As a result, the majority of these investigations corroborate the current results.

The correlation coefficient alone may offer a deceptive picture since it merely indicates the degree of mutual inclusion between two variables, regardless of causality. This is because there is a danger of overlooking certain important traits whose contributions via other attributes may be difficult to perceive. It is critical to quantify the relationships between the features of various plants and to define component attributes upon which selection techniques for direct and indirect genetic enhancement of agricultural output may be based (Hassan et al., 2013). In conjunction with Path analysis, Correlations would provide a more complete picture of the cause-and-effect connection between various pairs of characters. The path analysis component of the methodology divides the entire connection between the dependent variable and the independent component variable, i.e., the independent variable's direct influence on the dependent variable and its indirect effect through the third variable. As a result, route analysis is a critical technique for deriving independent and dependent variables' direct and indirect impacts. The phenotypic correlation coefficients for yield per plant were determined using the following characteristics: fruit weight, fruit diameter dry matter, total soluble solids leaf area, and vine length. This demonstrated that the observed variance was not just attributable to genetics but also the environment's effect. The selection process for developing such a character has a lot of room for improvement (Okoye and Eneobong, 1992, and Ullah et al., 2012). Fruit diameter had the most significant positive direct influence on total fruit yield/plant in the current study, followed by DM, TSS, and VL. While leaf area and frit weight directly influenced yield per plant, fruit weight had a favorable indirect effect. Through the qualities of FD, DM, TSS, and VL, we may select for greater yield by selecting for reduced fruit weight, suggesting that FW may indirectly influence other traits. As a result, we may consider that characteristic to be good for selection. It suggests that the direct selection of these features may be the only way to boost yield. Furthermore, leaf area and frit weight had a constant negative impact on total fruit yield/plant. It suggests that selecting these features directly may not boost yield. As a result, these characteristics must be selected indirectly through fruit yield per plant (Ndukauba et al., 2015). As a result, it appears that these parameters (FW and DM, VL, and TSS) are important factors in improving production variability. Previous studies have found similar impacts of component features on Yield (Solanki and Seth, 1980; Saikia et al., 1995; Singh, 1997; Singh et al., 2002; Verma, 2003; Kumar et al., 2008; Nandi et al., 2019).

Conclusion:

Our study's genotypic and phenotypic correlations indicated that the characteristics were highly heritable. Vine length, leaf area, fruit weight, fruit diameter, and total soluble solids all had a substantial positive phenotypic connection with yield per plant. According to the findings, fruit weight has a significantly substantial positive phenotypic association with Dry matter, Fruit Diameter, Leaf Area, and TSS characteristics. According to genotypic correlation, the yield exhibited a significantly significant positive link with fruit weight, leaf area, Dry matter, fruit diameter, and TSS characteristics. Path coefficients analysis for phenotypic and genetic demonstrated a direct positive influence on each plant's fruit output through fruit diameter, vine Length, dry matter, and total soluble solids in the current study. As a result, selection based on these qualities might be used to produce high-yielding genotypes reliably, and natural selection based on the aforementioned characters would be useful for cucumber crop development.

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